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ABSTRACT

This project experimentally evaluated the computer-based instruction (CBI) technology of the PLATO IV system. The approach was to conduct a set of eight research studies in different Navy training application areas. Short titles of the studies were: (1) remedial math, (2) oscilloscope simulation, (3) sine ratio, (4) multimeter simulation, (5) learner control, (6) recipe conversion, (7) oscilloscope guidance, and (8) part-task trainer. The final report summarizes the research design, method, results, and findings of each study. Experience, information, and data obtained from the research is then used to evaluate instructional effectiveness, technical features and characteristics, range of training applications, instructional material development methods and effort, and development and delivery costs. Conclusions are drawn and recommendations are made about the use of a PLATO IV type system for CBI. (Author)

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August 1976

EXPERIMENTAL EVALUATION OF PLATO IV TECHNOLOGY: FINAL REPORT

U.S. DEPARTMENT OF HEALTH, EDUCATION & WELFARE
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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This project experimentally evaluated the computer-based instruction (CBI) technology of the PLATO IV system. The approach was to conduct a set of eight research studies in different Navy training application areas. Short titles of the studies were: remedial math, oscilloscope simulation, sine ratio, multimeter simulation, learner control, recipe conversion, oscilloscope guidance, and part-task trainer.

The final report summarizes the research design, method, results, and findings of each study. Experience, information, and data obtained from the research is then used to evaluate instructional effectiveness, technical features and characteristics, range of training applications, instructional material development methods and effort, and development and delivery costs. Conclusions are drawn and recommendations are made about the use of a PLATO IV type system for CBI.

FOREWORD

This subproject is part of Advanced Development Project, Education and Training Development, ZPN07. An objective of the project is to test the feasibility of available new advances in training technology as a means of providing and maintaining increased personnel capability. This particular subproject was jointly sponsored by the Defense Advanced Research Projects Agency (ARPA); a principal focus of the ARPA/Joint Services Training Technology Program is the development of computer-based training for DoD-wide application.

Information on which this final report is based is the product of experience and data collected from a set of research studies performed during the 3-year life of the subproject. Navy Personnel Research and Development Center staff working on the studies included: J. D. Coady, A. M. Crawford, B. D. Ellis, P. Fredericks, W. A. King, G. F. Lahey, P. McCann, A. Sassano, H. W. Stern, and B. S. Whitehill. San Diego State University Foundation students working on the studies were L. Collins, L. Hoover-Rice, and R. Padilla.

Appreciation is expressed to the Chief of Navy Education and Training; the Commanding Officer, Service School Command, Naval Training Center, San Diego; the Commanding Officer, Fleet ASW Training Center, Pacific; and the Commanding Officer, Fleet ASW Wing, Pacific, and to their personnel who participated in the research studies, for their cooperation and assistance.

J. J. CLARKIN
Commanding Officer

SUMMARY

Problem and Purpose

This subproject was conducted as part of Education and Training Development, ZPN07 (formerly 43-03X) and was designed (1) to test the feasibility of new advances in computer-based training (CBT) systems, and (2) to apply new CBT methodologies to skills training. The subproject was jointly sponsored by the Defense Advanced Research Projects Agency. Objectives of the research were (1) to evaluate the capabilities and special features of the PLATO IV CBT System (2) to develop and evaluate CBT strategies and techniques for training on-the-job skills, and (3) to determine the applicability of PLATO IV to such skills training.

Approach

Experimental studies designed to evaluate PLATO features and CBT technology were conducted in a variety of Navy training applications. Training tasks for this evaluation included multimeter operation, oscilloscope operation, operation of S-3A copilot Integrated Control System (INCOS) panel, remedial mathematics, and recipe conversion. Computer-based training (CBT) techniques investigated included use of still, animated and interactive graphics, simulation, drill and practice, feedback in the context of games, guidance of offline instruction, learner control of instruction, and use of preprogrammed instructional strategies ("driver" lessons) for efficient course development. Data were obtained which provided estimates of training effectiveness and efficiency and cost effectiveness for both course materials development and course delivery.

Findings and Conclusions

1. The PLATO IV System is one of the most advanced and flexible CBI systems available operationally today for storing, controlling, and presenting training materials. Its instructional effectiveness for delivering all types and kinds of training is restricted only by the imagination and skill of instructional designers using the system. Its great capability may be a disadvantage because of the expensive CPU required: a large number of terminals must be utilized to decrease cost. If terminals are remotely located, communication and maintenance costs increase significantly.

2. The most useful terminal features are the plasma screen touch panel, and keyboard; the audio device and slide selector were judged the least useful.

3. PLATO IV is capable of providing instruction across a wide variety of Navy training. Seven different training applications were demonstrated in the experimental studies. It was found to be highly effective for training conceptual and cognitive skills and on-the-job skills involving

sequencing and procedural learning. One of the most innovative and potentially cost effective applications is in the use of programmable interactive graphic displays and touch panel for simulation.

4. It is estimated that operational training materials can be developed with from 200 to 400 man-hours of effort per hour of instruction. If each lesson hour of training materials cost between $1600 and $3200 and was used by 500 students per year for 10 years, the development cost would be approximately $.32 to $.64 per student contact hour. Development effort and costs can be minimized by using a team approach for development of instructional materials and by using driver lessons to reduce authoring and coding effort.

5. Delivery costs are the most expensive element of CBI. Terminal purchase and leased time-sharing could be amortized for approximately $3.90 per terminal hour, or $2.25 if a system were locally available. Purchase of a system with 250 terminals could be amortized for $1.75 to $3.00 per terminal hour, depending on speed of development of course materials.

6. Decisions to implement a PLATO IV type system for military training require a careful study of terminal utilization and the extent to which development costs can be amortized in order to determine potential cost savings and benefits. For operational use requiring a large variety of training applications, the present system should not be configured with over 500 terminals to allow for highly adaptive, individualized lessons.

Recommendations

1. Purchase and operational implementation of a large PLATO-type system should not be done at this time, because: (1) maximum cost benefits require operation at full capacity, (2) data on potential cost savings in specific applications are not available, and (3) the capabilities and costs of PLATO should be compared to those of competitive CBT systems before making a purchase decision (pp. 52, 57, 58, 65).

2. Lease of time from the University of Illinois PLATO System to run small units of terminals should not be done without a careful analysis of computing requirements for the particular applications under consideration. This is because limits on the use of extended core storage (ECS) restrict the capability for individualized training and prohibit complex part-task simulation applications. Leasing time from other private PLATO venders may avoid ECS problems but may be accompanied by higher delivery costs. Maximum benefits would again depend upon full utilization of terminals and avoidance of excessive communication costs. When only a few terminals are required or needed, small scale systems or stand-alone terminals may be more cost effective (pp. 42, 43, 58).

3. Two approaches are suggested in order to assess the proper role of CBT systems in Navy training. First, an analysis should be made of the potential for Navy CBT applications and their respective cost effectiveness. It was outside the scope of this project to do the necessary

needs analysis that would make it possible to identify specific Navy training needs and their current and/or anticipated costs. This information is required before it is possible to make recommendations on the operational utility and potential cost and training benefits that may be achieved using a large CBT system.

4. Second, additional R&D is needed to determine the kinds of skills that can best be taught using this methodology, especially potential cost effective part-task training applications using interactive graphic simulations, and to isolate necessary instructional elements that yield effective CBT.

TABLE OF CONTENTS

	Page
INTRODUCTION	1
Problem.	1
Purpose.	1
Background	1
APPROACH	3
SUMMARIES OF RESEARCH STUDIES.	5
Study One: Remedial Math.	7
Study Two: Oscilloscope Simulation.	11
Study Three: Sine-RatioConcept.	13
Study Four: Multimeter Simulation	15
Study Five: Learner Control	17
Study Six: Recipe Conversion.	19
Study Seven: Oscilloscope Guidance.	21
Study Eight: Part-Task Trainer.	23
EVALUATION OF PLATO FEATURES AND CAPABILITIES.	27
Author Use of PLATO Features	27
Instructional Methods.	27
Use of TUTOR	28
User Evaluation.	30
Authors and Coders	30
Student Questionnaire.	33
Student Comments	35
Maintenance.	36
PLATO Management Capabilities.	37
Student Performance Data	37
Computer Managed Instruction	38
Discussion of PLATO Features and Capabilities.	41
Stimulus Presentations	41
Interactive Capabilities	41
Course Management.	42
Course Preparation	42
System Capacity.	42
Reliability.	43

Page

DEVELOPMENT OF COMPUTER-BASED MATERIALS 45

General Description 45
Development Method. 45
Learner Control Driver. 48
Man-Hours of Effort Expended. 48

PLATO COST ANALYSIS 51

Instructional Materials Development Cost. 51
Instructional Delivery (Presentation) Cost Estimates. 53

Terminals 54
Time Sharing, Communications, and Maintenance 55
Total Delivery Costs. 56
Cost Comparisons with Other CBI Systems 58

CONCLUSIONS 59

Experimental Findings 59
Instructional Effectiveness 60
Training Applications 60
PLATO Features. 61
CBI Material Development Method and Effort. 62
CBI Delivery Cost 62
CBI Development Cost. 63

RECOMMENDATIONS 65

REFERENCES. 67
DISTRIBUTION LIST 69

LIST OF TABLES

1. Estimated Use of Instructional Techniques 27

2. Response Modes Available to Student 29

3. Lesson Features Requiring Highest Levels of TUTOR Programming (24 inputs from 10 authors) 29

4. Use of TUTOR. 30

5. Favorable Features of PLATO IV (41 inputs from 10 authors and 2 experienced coders) 31

Page

6. Problems in Use of PLATO IV (35 inputs from 10 authors and 2 experienced coders) 32

7. Student Questionnaire Responses. 34

8. Student Training Preferences 35

9. Student Comments on Oscilloscope Course. 36

10. Percent of Students Experiencing System/Transmission Problems. 37

11. CMI Data Format. 40

12. Summary Description of Computer-Based Materials. 46

13. Percentage of Development Effort by Team Member. 47

14. Programming/Coding Method. 47

15. Man-Hours Expended in Development. 49

16. Terminal Purchase Costs. 55

17. Annual Time Sharing Costs Minimum Terminal Configuration . . . 56

18. Comparative Delivery Costs per Student Contact Hour (10-Year Amortization). 57

LIST OF FIGURES

1. Student Data Trail Display. 39

INTRODUCTION

Problem

The Navy's support to the development of this subproject was in response to the requirements given in Advanced Development Objective (ADO) P4303 which states, "Required levels of personnel readiness and capability are highly dependent upon Navy education and training programs. Significant improvements in these programs must be achieved to meet increasing demands of future naval operations." An objective of the ADO is to test the feasibility of advances in training technology as a means of providing increased personnel readiness. To meet the ADO requirements, the objectives of this subproject were: (1) to test the feasibility of new advances in computer-based training (CBT) systems and techniques for providing part or all of modularized, individualized training programs, and (2) to apply new computer-based methodologies to skills training, including operator and maintenance training. The subproject is part of Advanced Development Project, Education and Training Development, ZPN07 (formerly P4303X).

Purpose

The Experimental Evaluation of PLATO IV Technology effort at the Navy Personnel Research and Development Center (NAVPERSRANDCEN) combined the evaluation of special capabilities of the PLATO IV system with the development and evaluation of CBT strategies and techniques for on-the-job skills. The purpose of the final report is to bring together the experiences and findings of the work efforts (eight studies) conducted on the project. Attention is given to summarizing the research studies and to drawing conclusions and making recommendations about instructional effectiveness, range of training applications, usefulness of special features and characteristics, implementation problems, and instructional development and delivery cost of the PLATO IV system for military training.

Background

This subproject on the Experimental Evaluation of PLATO IV Technology was conducted by NAVPERSRANDCEN, San Diego, and was jointly sponsored by the Defense Advanced Research Projects Agency (ARPA). A principal focus of the ARPA/Joint Services Training Technology Program is the development of computer-based training technology for DoD-wide application. The four objectives of the ARPA program are:

1. To provide advances in technology required to permit development and use of advanced training and educational delivery systems in the Armed Forces.

2. To provide research in learning behavior needed to set requirements for delivery systems, course development, and the production of course materials.

3. To facilitate the transfer of advanced training technology and research results to potential users and research agencies in the several Services.

4. To encourage and facilitate cooperation between the Services in research, development, and operational use of advanced training and educational delivery systems.

Research on PLATO IV conducted at the Service sites was intended:

1. To assess the training efficiency of the PLATO IV system on a variety of DoD curriculum packages.

2. To provide measures of PLATO reliability and operating costs.

3. To determine costs, problems and optimal methods for programming curriculum materials in PLATO IV format.

4. To assess the relative effectiveness of the TUTOR programming language.

5. To provide a basis of comparison with minicomputer CAI systems.

6. To acquaint operational training personnel with the capabilities and limitations of this advanced technology.

7. To provide Service R&D personnel with an advanced state-of-the-art system for CAI research.

8. To evaluate the general capability of the PLATO IV system.

ARPA support to NAVPERSRANDCEN covered installation, hook-up, communications, and maintenance of 12 PLATO terminals.[1] Through the cooperation of the Service School Command, Naval Training Center, San Diego, space was provided for the terminals in the Technical Training Building (Building #94, Room 344) which gave convenient access to trainees in a variety of Navy Schools.

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[1]Other Navy organizations which were part of the ARPA joint-supported PLATO IV program included the Office of Naval Research and the Naval Training Equipment Center.

APPROACH

Investigation areas included computer-based simulation of information displays, training strategies for problem solving and procedural learning, and techniques for Navy trainees with learning problems. The approach was to conduct a set of eight research studies that encompassed one or more of these investigation areas in their design. Studies identified by short titles were:

1. Remedial Math (McCann, 1975)
2. Oscilloscope Simulation (Stern, 1975)
3. Sine-Ratio Concept (King, 1975)
4. Multimeter Simulation (Lahey, Crawford, and Hurlock, 1975)
5. Learner Control (Lahey, Crawford, and Hurlock, 1976)
6. Recipe Conversion (Fredericks and Hoover-Rice, in preparation)
7. Oscilloscope Guidance (Slough and Coady, in preparation)
8. Part-Task Trainer (Crawford and Hurlock, in preparation)

It is important to point out that the project was a research and development effort:

1. Studies were planned, developed, and performed as experiments. Although internal comparisons of computer-based training materials were often made against conventional instruction, the purpose was not to prove that CBT using PLATO IV was superior or better. The relative superiority of CBT over class instruction has been amply demonstrated (e.g., Ford and Slough, 1970; Hurlock, 1972; Ford, Slough and Hurlock, 1972). CBT has also been shown to produce faster learning than self-paced instruction (Army Final Report, 1975). Comparisons were made to determine where and how particular PLATO IV applications could be successfully used in operational Navy training.

2. The tryout and revision cycles necessary to develop CBT materials which are instructionally more effective (improve performance significantly) and efficient (yield significant training time savings) than conventional methods (Ford, Slough, and Hurlock, 1972) were not a procedural step included in the PLATO experiments.

3. The effort was not intended as a prototype test bed to evaluate operational training capability or cost for a large integrated course of instruction. Such a test bed evaluation was conducted by the Army (Evaluation of the PLATO IV System, 1975). The present project evaluated effectiveness, problems, and optimal methods in using PLATO in a variety of operational settings.

SUMMARIES OF RESEARCH STUDIES

This section presents a brief summary of each of the eight research studies performed at NAVPERSRANDCEN, San Diego. The purpose of these summaries is to enable the reader to quickly learn the rationale, research design, results, findings, and conclusions of each study. References provided in each summary indicate source documents which contain more detailed information; for example, a separate NAVPERSRANDCEN Technical Report has been or will be published on each study.

The reader is cautioned that each study was designed and executed as a research and development (R&D) effort to answer specific questions concerning PLATO applications and not as an attempt to develop instructional course material solely to evaluate operational effectiveness. Research findings reported in each summary are, therefore, specific only to that particular study. Generalizations across studies have been made in later sections, especially in the final section on conclusions and recommendations.

Later sections cover special information obtained and collected on each study. Topics include: (1) descriptions of method used and effort involved in course material development, (2) evaluation of PLATO features and capabilities, and (3) analysis of cost of developing and delivering instruction.

Study One: Remedial Math

Reference: McCann, P. H. Training mathematics skills with games. San Diego: Navy Personnel Research and Development Center, Technical Report 75-28, April 1975.

I. Purpose/Rationale: The goal of this study was to test the efficiency of the games presented by the PLATO IV System in remedial mathematics training for Basic Electricity/Electronics (BE/E) School trainees. The idea was to create an intrinsic motivation in remedial students during practice to improve their mathematics skills by making moves of a game a part of their feedback.

II. Research Design

A. Course Description

1. Subject Matter Area: Basic algebra formula manipulation, powers-of-ten scientific notation and computational skills.

2. Major Training Tasks: (a) Correctly add, subtract, multiply, divide, square, and extract square roots of numbers expressed as powers of ten, and (b) transpose formulas with correct placement of decimal point; identify and use correct metric prefixes.

3. Number of Student Contact Hours Developed: 3 hours.

B. Experimental Design

1. Design: Each student took two CAI lessons presenting practice on different kinds of math and received a different kind of feedback (conventional, conventional plus game #1 play move, or conventional plus game #2 play move) during each lesson.

2. Independent Variables: Three kinds of feedback.

3. Dependent Variables: Lesson time, test score, and attitude questionnaire responses.

4. Subjects: 48 BE/E School students requiring remediation in mathematics.

III. Results

A. Principle Data

1. Mean Performance

Performance Measures	Feedback Method	Type of Math: Powers-of-Ten	Type of Math: Formula Solving
Test Scores (%)	Conventional	82	47
	with Game #1	70	50
	with Game #2	81	54
Lesson Time (min.)	Conventional	23	22
	with Game #1	24	28
	with Game #2	28	26

2. Responses to Questionnaire

Question	Response Frequency				
Which type of problem solving did/would you prefer?	Regular Practice (14)		Game Practice (34)		
If you played both Game #1 and Game #2, which did you prefer?	Game #1 (2)		Game #2 (14)		
In future lessons, what % of problem-solving practice would you like in game form?	0-10% (4)	25% (7)	50% (15)	75% (12)	100% (10)

B. Major Statistics Employed to Analyze Data: Multivariate analysis of variance and covariance; Biomedical Computer Program Series, UCLA BMD12V.

IV. Findings

A. Receiving game move plays as part of feedback to practice problems did not result in changes in student test performance or training time.

B. Students indicated strong and favorable preferences for practice having feedback with games.

V. Conclusions

A. Being able to make play movements in a game as part of the feedback for practice problems in math may not be the best use of gaming capabilities for the PLATO system because moves did not produce different results in achievement or training time over conventional right-wrong feedback.

B. The fact that students indicated high preference for gaming with practice is important and points to other ways to take advantage of the gaming to influence both attitudes and performance. A superior use of gaming to aid training would be to employ a contingency management point (token) system during practice. Here students would be given control to select or choose the number of practice problems they want; for each correct answer they would receive points. Time or play moves on games, available on PLATO, could then be "purchased" with the earned points. Thus, the opportunity to play games would be contingent upon the student taking practice and answering correctly. This arrangement should produce high motivation to practice and answer correctly; it has the potential to improve performance. The PLATO system is ideally suited for contingency management of learning and practice during training using games.

Study Two: Oscilloscope Simulation

References: Stern, H. W. Transfer of training following computer-based instruction in oscilloscope procedures. San Diego: Navy Personnel Research and Development Center, Technical Report 76-1, July 1975.

I. Purpose/Rationale: Extensive equipment is required to provide hands-on training for operation of oscilloscopes. The purpose of this study was to determine the amount of transfer of training provided by oscilloscope simulation using the PLATO IV terminal.

II. Research Design

A. Course Description

1. Subject Matter Area: Oscilloscope operation.

2. Major Training Tasks or Objectives: Adjust oscilloscope to obtain line trace, calibrate probe, measure voltage, measure frequency.

3. Number of Student Contact Hours Developed: 5.2 hours.

B. Experimental Design/Conditions

1. Design: Performance of students trained on PLATO was compared with that of students trained on actual oscilloscope equipment. The PLATO training used plasma screen graphics and microfiche image projection to simulate oscilloscope operation. Both groups were given a performance test on the actual equipment immediately after training and again after additional "A" school oscilloscope experience.

2. Independent Variables: Simulation versus actual oscilloscope operation.

3. Dependent Variables: Scores on performance test tasks; performance test time.

4. Subjects:

Number of Subjects Used: 20 CAI and 29 Non-CAI
Student Characteristics: Sonar "A" school trainees

Measure		GCT	ARI	ETST
Mean Scores	CAI:	61	58	64
	Non-CAI:	62	58	67

III. Results

A. Principle Data

Adjusted Mean Scores and Times on First Performance Posttest

Performance Measures	GR1 PLATO	GR2 Laboratory
Total Score	54	60
Obtain trace and stabilize display	42	60
Calibrate probe	19	43*
Measure voltage and frequence	65	40*
Total Performance time (min.)	23	19*

*Significant difference between groups.

B. Major Statistics Employed to Analyze Data: Analysis of Covariance.

IV. Findings

A. The groups did not differ significantly in overall performance on the immediate posttest, although the PLATO group required longer to complete the test.

B. Simulation was more effective than the laboratory training for voltage and frequency measurement tasks but was less effective for tasks involving manipulation of controls.

C. Both types of training provided adequate background for further practice. The groups did not differ on the second performance test.

V. Conclusions

A. Simulation using a general-purpose CBI system such as PLATO is most effective for tasks involving cognitive skills and least effective for tasks involving specialized perceptual motor skills. Thus, simulation of voltage and frequency measurement, which requires only CRT displays and pencil and paper responses, was superior to laboratory training. However, simulation of probe calibration, which requires skilled manipulation of the probe, yielded very poor performance.

B. A task as complex as oscilloscope operation requires some training on the actual equipment, but the amount needed is rather small. Although simulation trainees had never used the equipment before, they did nearly as well on the hands-on performance posttest as trainees with 4 hours of experience on the actual scope.

Study Three: Sine-Ratio Concept

Reference: King, W. A. A comparison of three combinations of text and graphics for concept learning. San Diego: Navy Personnel Research and Development Center, Technical Report 76-16, September 1975.

I. Purpose/Rationale: This effort was planned to study ways to take advantage of the terminal graphic display capabilities of PLATO IV for computer-based instruction. The research specifically examined how verbal instruction (text) for learning the sine-ratio concept could be supplemented by visuals (graphic displays).

II. Research Design

A. Course Description

1. Subject Matter Area: Sine-ratio concept; trigonometry; right triangle.

2. Major Training Tasks or Objectives: (a) Use of formula, $\sin \theta = \frac{opp}{hyp}$ to calculate value of angle θ and (b) transposition of the formula.

3. Number of Student Contact Hours Developed: 1.2 hours.

B. Experimental Design/Conditions

1. Design: Three independent treatment groups: (a) text alone (control), (b) text and static graphics, and (c) text and animation. All groups took an identical performance test before and after training.

2. Independent Variables: Computer-based training conditions: (a) text alone, (b) text and static graphics, and (c) text and animated graphics.

3. Dependent Variables: Pretest and posttest scores; training time.

4. Subjects: Total = 45 (15 per group). Trainees from BE/E School; mean GCT = 56 and mean ARI = 50.

III. Results

A. Principle Data

Conditions	Groups		
	Text	Text & Graphics	Text & Animation
Mean Pretest Score (% correct)	67.4	62.9	71.8
Adjusted Mean Posttest Scores (% correct)	81.2	80.3	85.3
Mean Training Time (minutes)	37.6	33.1	35.7

B. Major Statistic: Analysis of Covariance

IV. Findings

A. Significant learning took place between pre- and posttest for all three groups.

B. No significant difference was found between the adjusted post-test scores for the three groups.

C. Student attitude to the lesson was positive and ratings of instructional materials and presentation were high.

V. Conclusions: Graphics were not found to enhance learning of the verbal loaded sine-ratio concepts in this study. However, other studies in the project (e.g., Multimeter Simulation and Part-Task Trainer) clearly demonstrated that static, dynamic, and interactive graphics are some of the most useful and important pedagogical features of PLATO IV.

Study Four: Multimeter Simulation

References: Lahey G. F., Crawford, A. M., & Hurlock, R. E. Use of an interactive general-purpose computer terminal to simulate training equipment operation. San Diego: Navy Personnel Research and Development Center, Technical Report TR 76-19, November 1975.

I. Purpose/Rationale: To demonstrate that a general-purpose computer terminal can be used successfully to develop operational as well as cognitive skills by simulating use of operational equipment in a training environment.

II. Research Design

A. Course Content

1. Subject Matter Area: Use of Simpson Model 260 multimeter as ohmmeter and ammeter; basic electricity/electronics.

2. Major Training Tasks or Objectives: Deenergizing/energizing circuits, connecting probes, setting circuits, zeroing the meter, connecting the meter, reading and interpreting.

3. Number of Student Contact Hours Developed: 4 hours.

B. Experimental Design

1. Design: Factorial design using independent groups to compare training using CAI and BEEINLES materials.

2. Independent Variables: CAI lessons with interactive graphic simulation of multimeter versus BEEINLES materials and actual gear.

3. Dependent Variables: Time spent in training; scores on performance tests and module exams.

4. Subjects: 42 control and 42 experimental students used in evaluation.

III. Results

A. Principle Data

Variable	Group: Experimental	Group: Control
Module Exam. (%)	91.9	93.6
Criterion questions	92.0	91.0
Training Time (hours)	13.8*	11.9

*$p < .05$

B. Major Statistics Employed to Analyze Data: Analysis of Variance.

IV. Findings

A. Simulation of the multimeter for use in a learning and training mode was successful.

B. CAI-trained students using a simulated meter did not have a decrement in test performance. Longer training time was primarily attributed to administrative handling necessitated by the experimental conditions and to students taking extended practice using the learner control strategy. Students were enthusiastic about the instructional method.

V. Conclusions

A. PLATO graphics and TUTOR language are highly suited for programming dynamic and interactive simulations of military gear and equipment.

B. Training using simulation may offer an instructional technique for reducing cost of training and training equipment, for making training safer, and/or for providing a readily available training capability.

Study Five: Learner Control

References:

Hurlock, R. E., & Lahey, G. F. Learner controlled driver lesson. Proceedings of ADCIS Summer Meeting. August 1974, pp. 183-188.

Lahey, G. F., & Crawford, A. M. Learner control of lesson strategy: Some tentative results. A paper read at American Educational Research Association 1976 Annual Meeting, San Francisco, April 1976.

Lahey, G. F., Crawford, A. M., & Hurlock, R. E. Learner control of lesson strategy: A model for PLATO IV system lessons. San Diego: Navy Personnel Research and Development Center, Technical Report TR 76-36.

I. Purpose/Rationale. Investigate methods and techniques for developing CAI lessons with minimum author/coder effort. Specifically: to develop a preprogrammed set of instructional strategy logics (learner control) capable of independently "driving" a variety of lesson subject matter content. The "driver" would be available on the PLATO system for any author to use; author would only have to be concerned with developing his lesson content; coder would only have to program lesson content. Driver would provide strategy and format the lesson content into instructional presentations.

II. Research Design

A. Course Content: The driver consisted of two major parts (1) Author mode: TUTOR programming of learner control logics and course and format organization files--all with self-contained instruction on how to use driver and insert content, and (2) Student mode: a complete self-instructional course designed to describe and explain how the driver works and how to organize and write lesson content to use with the driver.

B. Course Design: "Driver" was designed and modeled after the "Learner Control" paradigm described by M. David Merrill. Lesson content required organization by training objectives formatted into easy, medium, and hard files of rules, examples, and practice statements. Coding of content could require as few as three TUTOR commands--Insert, Replace, and Delete. Practice problems have a multiple-choice format and may require additional lesson file space.

C. Experimental Design: Evaluation of technical feasibility was demonstratable by ability of logics to drive its own self-instructional lesson content in student mode. Operational feasibility was tested by using the "driver" as the base for two other PLATO research study lessons.

III. Results

A. A learner control driver lesson was designed, developed, and programmed for use on the PLATO system.

B. The operational feasibility of the driver was demonstrated by its successful use as a base for CBI lessons in two of the PLATO research studies--Multimeter Simulation and Recipe Conversion. Students who used the learner control strategy in these studies learned as well and as quickly as controls.

C. Potential economic feasibility of using the driver to aid in lesson preparation was shown during development of lessons for the Recipe Conversion study. Authors and coder had no prior experience using the TUTOR programming language. A total of 8.8 student contact hours of instruction were developed with a mean man-hour effort of only 77 hours per hour of instruction.

IV. Conclusions: The use of a preprogrammed, "universal" driver to control lesson strategy can eliminate a major part of the task of lesson preparation and offers a significant method to save both author training and lesson preparation time.

Study Six: Recipe Conversion

Reference: Fredericks, P. A., & Hoover-Rice, L. B. An evaluation of learner-controlled computer-assisted instruction and traditional instructor-classroom techniques for recipe conversion. San Diego: Navy Personnel Research and Development Center, Technical Report (in preparation).

I. Purpose/Rationale: To investigate the feasibility of using computer-based instruction (CBI) for nontechnical Navy training and for students with below average aptitudes. Specific subgoals of the research evaluated the use of computer-based individualized instruction under student control for Mess Management Specialist rating and a comparison of math versus job aids training for solving recipe conversion problems.

II. Research Design

A. Course Description

1. Subject Matter Area: Mess Management; Armed Forces Recipe Service; Recipe Conversion.

2. Major Training Tasks or Objectives: Convert standard recipe, based on 100 servings, to accommodate either a limiting ingredient or a different number of servings using either a mathematics or job aid cards solution.

3. Number of Student Contact Hours Developed: 8.8 hours.

B. Experimental Design/Conditions

1. Design: Three independent groups: (a) a control group received conventional classroom lecture instruction on using math solutions, (b) an experimental group received CBI on using math solutions, and (c) an experimental group received CBI on using job aids to solve problems. The CBI for both experimental groups was individualized and under student control; CBI began with a pretest and ended with a post-test. All groups took the school's final examination.

2. Independent Variables: (a) Conventional training versus two types of CBI and (b) use of math versus use of job aids to solve recipe conversion problems.

3. Dependent Variables: Pre- and post-lesson quiz scores, attitude questionnaire responses, and training times for experimental groups. School's final examination scores for all groups.

4. Subjects: Total of 60 students, 20 per group. Navy trainees from Mess Management Specialist Class A School, NTC, San Diego. Average GCT = 53, ARI = 52. About 38% of students below GCT/ARI of 100.

III. Results

A. Principal Data

	Experimental Groups		Control Group
Measure	CBT Math	CBT Job Aids	Class Instruction
Training Time	4.34 hours	4.44 hours	4 days (appx. 28 hrs)
Pre-lesson Quiz (%)	27	32	
Post-lesson Quiz (%)	87	88	
Final Exam (%)	91.9	91.3	95.6

B. Major Statistics Employed to Analyze Data: Analysis of Covariance

IV. Findings

A. CBI resulted in a very great savings in training time (4.5 hours versus 28 hours).

B. Gains on lesson quiz scores, final exam scores, and training time between the two experimental groups were not different.

C. Experimental groups did not differ from the classroom instructed group on the final exam following training.

V. Conclusions: Results indicate that student-controlled, individualized computer-based instruction in non-technical Navy training can be used to decrease significantly training time without degrading the performance of trainees with below average academic skills. Low aptitude students did not report difficulty in using the PLATO terminal.

Study Seven: Oscilloscope Guidance

References: Slough, D. A., & Coady, J. D. Strategies for computer guidance of oscilloscope training. San Diego: Navy Personnel Research and Development Center, Technical Report (in preparation).

I. Purpose: To investigate the feasibility of computer guidance of hands on training of equipment operation, and to identify an effective sequencing strategy for such instruction.

II. Research Design

A. Course Description

1. Subject Matter: Oscilloscope operation.

2. Major Training Tasks: Adjust oscilloscope to obtain a line trace, calibrate probe, measure voltage, measure frequency.

3. Number of Student Contact Hours Developed: 12 hours.

B. Experimental Design

1. Method: Basic instruction consisted of "criterion practice" in which trainees operated the actual oscillscope equipment, with instructions, feedback, and an extensive set of nested help options available from the PLATO terminal. A control group (CP) received only this criterion practice and was compared with three types of pretraining: (a) FC trainees were first taught the functions of the controls, (b) PP trainees were given prompted practice in obtaining a line trace, and (c) BC (backward chaining) trainees were taught voltage and frequency measurement before learning to adjust the oscilloscope. An additional comparison was made with standard non-CAI training (data from Stern, 1975).

2. Independent Variable: Instructional sequencing.

3. Dependent Variables: (a) Total training time, (b) hands-on performance test score, and (c) written test score.

4. Subjects

Number and Type:	CAI:	48 Basic Electronics Trainees	
	Non-CAI:	18 Sonar A School Trainees	
Mean Test Battery Scores:	GCT	ARI	ETST
CAI:	58	56	63
Non-CAI:	62	58	67

III. Results

A. Principal Data

Performance of Computer Guidance and Non-CAI Students

Measure	Computer Guidance				Non-CAI
	CP	FC	PP	BC	
Training Time (hrs)	4.1	3.7	3.1	3.3	4*
Performance Test (%)	88	92	93	90	61
Written Test (%)	69	79	74	78	--

*fixed schedule

B. Major Statistics Used to Analyze Data: Analysis of covariance.

IV. Findings

A. Posttest performance of CAI students in all groups was markedly superior to performance of trainees receiving standard non-CAI individualized instruction. The principal reason for this is probably because the CAI students were provided with constant personal tutoring by the computer as they practiced.

B. The prompted practice and backward chaining groups required significantly less training time than the control group, but the usefulness of the "function of controls" pretraining was not clear. In addition, the backward chaining group tended to work slightly faster on the posttests (less time required for the written posttest and for hands-on measurement of voltage and frequency).

V. Conclusions

A. Computer guidance of hands-on training is an effective instructional procedure. It was possible to provide extensive tutoring at a fraction of the cost of an actual instructor by using a CBT program combined with simple techniques such as marked covers for signal generator dials which allowed the student to practice with unknown signals.

B. Part-task procedural training seems to be better than whole training (CP group) if the part task is an actual and unitary component (group PP or BC) of the criterion task.

C. Simulation of cognitively-loaded tasks such as voltage and frequency measurement is a highly effective training procedure, confirming Stern's (1975) results.

Study Eight: Part-Task Trainer

References:

Crawford, A. M. Low cost training using interactive computer graphics. Paper accepted for publication in the Proceedings of the Fifth Psychology in the Air Force Symposium, Colorado Springs, Colorado, April 1976.

Crawford, A. M., Hurlock, R. E., Sassano, A., & Padilla, R. Part-task training using interactive computer graphics for simulation of operational equipment: A low-cost training methodology for performance-oriented skills. San Diego: Navy Personnel Research and Development Center, Technical Report (in preparation).

I. Purpose/Rationale: Evaluate PLATO IV language and terminal capabilities--graphics, touch panel, and keyboard--to perform unique, Navy specific part-task training and simulation. Estimate technical, operational, and economic feasibility of PLATO as a low cost simulation trainer.

II. Research Design

A. Course Content

1. Subject Matter Area: S-3A copilot Integrated Control System (INCOS) panel operation.

2. Major Training Tasks or Objectives

a. Operate all front panel controls.
b. Modify computer display tableaus.
c. Respond to alerts and cues.
d. Manipulate display symbology.

3. Number of Student Contact Hours Developed: 3 hours.

B. Experimental Design/Conditions

1. Design: Two independent groups (Experimental--PLATO trained and Control--workbook trained) with repeated measures (two performance tests).

2. Conditions: Each group underwent their respective methods of training. Then, in a Position Trainer, each group took a performance test (PT1), practiced exercises for one hour and took a second performance test (PT2).

3. Independent Variables: Training method: 3 hours of computer-based training using interactive graphics versus 8 hours of workbook training.

4. Dependent Variables: Time to complete problems on each performance test and number of problems completed on each test.

5. Subjects:

Number Used: 44 (22 in each group)
Characteristics: Trained copilot in first week on S-3A training at FASOTRAGRUPAC, NAS, North Island.

III. Results

A. Principal Data

	Mean Time (minutes)		Mean Number Completed	
Group	PT1	PT2	PT1	PT2
Experimentals	2.85	1.88	1.68	2.00
Controls	4.44	3.32	1.18	1.73

B. Major Statistics Employed to Analyze Data: 2 x 2 factorial analyses on each dependent measure analyzing the types of training and the form of the PT administered for comparisons: (1) experimental versus control on PT1, (2) experimental versus control on PT2, and (3) experimental on PT1 versus control on PT2.

IV. Findings

A. On the first performance test (PT1) given in the high fidelity Position Trainer, experimental students completed significantly more problems and finished quicker than workbook trained students.

B. After a 1-hour practice exercise in the Position Trainer, experimental students continued to show significantly superior ability on the second performance test (PT2).

C. No statistical difference was found between the performance of PLATO students on PT1 and that of the workbook students on PT2.

V. Conclusions

A. Data indicate that, given the currently accepted levels of training proficiency, 3 hours of part-task computer-based training could substitute for 8 hours of workbook study and 1 hour of practice in an expensive position trainer.

B. The study demonstrated the technical and operational feasibility of part-task training via computer-based simulation, i.e., interactive graphics and touch panel response mode on PLATO IV. In addition, PLATO training delivered at $5.00/hour may be economically feasible since it could replace: (1) instructor time required to individually practice each student in the position trainer, (2) 8 hours of student time allotted to the workbook, and (3) an hour of position trainer time which costs $250.00/hour.

EVALUATION OF PLATO FEATURES AND CAPABILITIES

Author Use of PLATO Features

Instructional Methods

Data on the use of instructional techniques and associated PLATO capabilities were obtained from the authors of each of the eight experimental studies. Table 1 gives the relative frequency of use (mean and range in percent) of various instructional methods. The studies emphasizing simulation (oscilloscope simulation, oscilloscope guidance, multimeter simulation, part task trainer) are grouped together because they differed considerably from the other four studies in methodology employed.

TABLE 1

ESTIMATED USE OF INSTRUCTIONAL TECHNIQUES

Instructional Technique	Nonsimulation (4 studies) $\bar{x}$ (range)	Simulation (4 studies) $\bar{x}$ (range)
Stimulus Presentation (%)		
Text	67 (30-85)	20 (10-30)
Graphics	33 (15-70)	66 (50-85)
Microfiche	-	14 (0-40)
Sequencing (%)		
Linear	26 (0-50)	12 (0-30)
Adaptive		
Student control	63 (20-100)	67 (20-100)
System control	11 (0-75)	21 (0-50)
Training Interactions (%)		
Multiple choice	95 (90-100)	17 (1-55)
Interactive graphics	-	50 (10-98)
Constructed responses	5 (0-10)	33 (1-83)

As might be expected, the simulation studies made heavy use of graphics for stimulus presentation. However, even in the nonsimulation experiments, an estimated 33% of stimulus materials consisted of plasma screen graphics.

The microfiche capability was used in a significant amount in only two studies--oscilloscope simulation and oscilloscope guidance. Also, usage was considerably less than originally planned because of difficulties in obtaining acceptable quality and alignment of displays. Attempts to use microfiche images of job aid cards in the recipe conversion study were so unsuccessful that graphics and hardcopy handouts were used instead.

All studies made extensive use of adaptive training methods, with little emphasis on simple linear sequencing. Student control of sequencing was the most popular method, although there was wide variation from study to study, as can be seen from the ranges in Table 1. The adaptive techniques require heavy use of PLATO's file handling, branching, and response processing capabilities.

Simple multiple choice was by far the most popular responding method in the nonsimulation studies but was little used in the simulation lessons. The part-task trainer used interactive graphics almost exclusively: the S-3A control console was simulated using plasma screen graphics and the touch panel. Constructed responses were quite frequently used in the oscilloscope studies because a large part of the task involved measurement of voltage and frequency.

Table 2 shows response modes made available to students by authors. The function keys ("help," "data," etc.) were not as widely used for sequencing as other modes, although they were expressly designed for this purpose. The touch panel had not yet been delivered when three studies were run and was not used by choice in a fourth study. Where the touch panel was available, it was a popular method for both sequencing and responding to instructional content. Several authors provided the student with a choice of response mode, e.g., either touch panel or alphanumerics for multiple choice answers.

Use of TUTOR

The data on instructional techniques previously summarized in Table 1 suggests that the simulation studies made more extensive use of TUTOR capabilities than did the other studies. This is corroborated by the author comments summarized in Table 3. For each study, the authors were asked to list the three lesson features which required the highest levels of TUTOR programming. Training interactions, including task simulation, response processing, and use of games, were mentioned most often (38%). Stimulus simulation accounted for 21% of the comments and, when added to the 17% for task simulation, brought the total for simulation to 38%.

Lesson control comments (29%) included complex decisions based on both amount and accuracy of responding, and data manipulation problems. For example, data storage sometimes required bit manipulation in order to make effective use of the available computer space.

TABLE 2

RESPONSE MODES AVAILABLE TO STUDENT

Response Mode	Touch Panel Not available (4 studies) $\bar{x}$ (range)	Touch Panel Available (4 studies) $\bar{x}$ (range)
Sequencing (%)		
Function keys	37 (0-100)	20 (10-25)
Alphanumerics	63 (0-100)	9 (0-15)
Touch panel	-	21 (0-85)
Student choice	-	50 (0-80)
Training Interactions (%)		
Alphanumerics	100	29 (0-80)
Touch panel	-	27 (0-99)
Student choice (Touch panel or other	-	44 (0-100)

TABLE 3

LESSON FEATURES REQUIRING HIGHEST LEVELS OF TUTOR PROGRAMMING (24 inputs from 10 authors)

Comment	Percent of Comments	
Training Interactions		38
Task Simulation	17	
Response processing and corrective feedback	17	
Games controlled by student performance	4	
Stimulus Presentation		21
Dynamic simulation	13	
Detailed simulation (scales, etc.)	8	
Control of Sequencing and Content		29
Provisions for student control	13	
Complex decision making	8	
Data storage and processing	8	
Performance Data Recording		12

Performance recording complexities were mentioned in 17% of the comments. It should be noted, however, that these were experimental studies. Performance data collected was considerably more extensive than would be required in an operational course.

Authors were asked to rate the extent to which their lessons made use of the capabilities of TUTOR, using a scale from 1 to 10 (1 = simple series of text presentations, etc.). Results are given in Table 4. The mean rating was twice as high for the simulation studies as for the non-simulation studies.

TABLE 4

USE OF TUTOR

Item	Nonsimulation Studies $\bar{x}$ (range)	Simulation studies $\bar{x}$ (range)
Rating of use of TUTOR capabilities (1 = minimum, 10 = maximum)	4 (3-8)	8 (7-9)
ECS words per hour of instruction		
Instruction all on line	(3 studies) 5.8K (4.0-8.2)	(3 studies) 9.6K (3.9-16.0)
Instruction partly off line	(1 study) 2.2K	(1 study) 2.6K

Table 4 also gives the average amount of extended core storage (ECS) used per student contact hour. Although there is considerable variation from study to study, the simulation studies required about 50% more space for each on-line hour. Also, the longer courses tended to make more efficient use of computer storage space.

User Evaluation Data

Authors and Coders

Project members were asked to list and briefly describe the favorable features of PLATO IV. Data were collected from 10 authors and 2 experienced coders who had worked on the project since its beginning. Results are shown in Table 5.

TABLE 5

FAVORABLE FEATURES OF PLATO IV
(41 inputs from 10 authors and 2 experienced coders)

Comment	Percent of Comments	
TERMINAL FEATURES		49
Plasma screen	30	
Graphics-15 (dot control, realism, animation)		
Other-15 (useful displays, no flicker, no refreshing, ease of erase)		
Touch panel (screen position input, graphics)	10*	
*Mentioned by all 4 users		
Versatile terminal	5	
Quiet terminal	2	
Keyboard with function keys	2	
TUTOR LANGUAGE		27
Flexible, versatile, powerful	15	
Ease of editing, coding	10	
(Editing-8, coding-2)		
Easy to learn simpler coding	2	
SYSTEM FEATURES		24
User services and aids	12	
(Consultation, access to other programs, router lesson, data collection file, hard copy device)		
Fast response time	10	
(CPU-8, screen refreshment-2)		
Storage and processing capacity	2	

Terminal features account for 49% of the favorable comments. The plasma display screen was a clear favorite, receiving 12 comments (30%). The touch panel was also well received. Although only four studies used the touch panel, it was mentioned by all four users. Several of the comments mentioned the combined use of the plasma screen and the touch panel for simulation purposes.

Another popular feature (27%) was the TUTOR language, with most comments mentioning its versatility or the editing and coding capabilities. User services and aids was next with 12% of the comments. These services, which were provided by the University of Illinois, were quite important in reducing the effort required for materials preparation.

Fast response time was also frequently mentioned (10%) as a favorable feature. Many experienced CAI authors feel that slow response times are distracting to the student and apt to interfere with learning.

Authors and coders were also asked to list and describe the major problems they encountered in use of PLATO. A summary of the replies is given in Table 6.

TABLE 6

PROBLEMS IN USE OF PLATO IV
(35 inputs from 10 authors and 2 experienced coders)

Comment	Percent of Comments	
SYSTEM		43
Space problems (ECS limitations-8, condensing-6, student scheduling-6, too many users-3)	23	
Reliability (crashes-8, downtime-6)	14	
Continued system development and changes	3	
Student can miss material because of pile up of "next" key presses	3	
TUTOR LANGUAGE		26
Too complex (too many commands-8, variations in format-6, command interactions and exceptions-6, response processing cumbersome-3)	23	
Constant changes	3	
TERMINAL FEATURES		17
Microfiche system unacceptable *Mentioned by both users (poor fidelity-6, alignment problems-6, turn around time too long-3)	14*	
Terminal noise	3	
TRANSMISSION		14
Line errors	14	

Space problems accounted for 23% of the replies. These problems included limitations in ECS in designing materials and in running students, condensing problems during busy periods of the day, and some student scheduling problems in a few of the studies because of user site allocation difficulties.

The TUTOR language was considered too complex by many users (23% of comments). Problems included too many commands, lack of consistency in format, and a tendency for modifications to make the language more complex, rather than simpler.

Problems in running students (other than space problems already covered) included system reliability (14%) and transmission line errors (14%). System crashes usually resulted in student data being lost or garbled. Line errors frequently distorted displays and were particularly troublesome in the simulation studies. For the simpler lessons, a routine was prepared which made it easy to refresh the screen by using the "term" key. However, for the more complex lessons, this was not possible because of the complicated coding required; here it was necessary to sign the student off and back on again (sending him back to the last restart point).

It should be noted that line errors are not the fault of the PLATO system. However, they produce a limitation on the effectiveness of using terminals at remote sites.

Although the microfiche image projector was used in only two studies, it received a total of five unfavorable comments (14% of all comments) from these two users. It was very difficult to align the images with graphic or text material and very difficult to obtain reproductions of satisfactory quality.

Student Questionnaire

A questionnaire was prepared covering use of terminal features, problems in training, and evaluations of instructional effectiveness. This questionnaire is on line on PLATO and contains automatic data analysis routines.

The questionnaire was administered to students in all studies except the Part Task Simulator study where time restrictions precluded its use. Data from 310 students are shown in Table 7. On each question, the student gave his rating on a 5-point scale. For items such as the screen color combination, the scale was from "unacceptable" (1) to "ideal" (5). For items such as asking for help, the scale was from "often" (1) to "never" (5).

Average ratings were quite high for almost all items, with the typical rating being 4 or better. Lowest ratings were for quality of the photographs and getting the terminal to work right, but even these were acceptable to most students.

TABLE 7

STUDENT QUESTIONNAIRE RESPONSES

Item	Mean Rating (1 = very negative) (5 = very positive)
Displays	
Black and orange color combination	4.4
Ease of reading displays	4.6
Material crowded on screen	4.4
Arrangement on screen	4.3
Quality of photographs	3.6
Keyboard	
Keyboard design	4.2
Movable keyboard	4.2
Special keys	4.4
Potential Problems	
Fatigue	4.2
Reflections on screen	4.4
Eye strain	4.7
Waiting for new displays	4.3
Getting terminal to accept correct answer	4.2
Getting terminal to work right	3.6
Instructional Effectiveness	
Rating of computer based training	4.1
Instructional effectiveness of materials	4.0
Objectives clear	3.8
Had to ask for help	4.2
Figuring out what to do next	3.9

Students experienced very few problems in their computer-based training. There was little fatigue or eyestrain reported. Waiting for new displays did not bother the trainees, although the simulation studies frequently had complex displays which required several seconds to generate. Display delays are probably more bothersome to authors and coders, who may have to look at a display many times during development and debugging.

Students gave a high rating (4.1) to computer-based training. Since most of the trainees came from a course in which they had had individualized self-paced instruction, it was possible for them to state a meaningful preference for different types of instruction. Table 8 lists

the student preferences for the amount of training they would like by each of three methods--class, individualized, and CBT. The mean percent of training preferred is roughly the same for all three methods, with a slightly lower preference for classroom instruction.

TABLE 8

STUDENT TRAINING PREFERENCES

Type of Training Preferred	Mean Percent of Training
Classroom and textbook	31
Self-instructional booklets	35
Computer based training	34
Mixture of Training Preferred	**Percent of Students**
One type only	20
Combination	80

The bottom of Table 8 shows that only 20% of the students preferred to have one kind of training exclusively. The majority liked a combination of the three types. This finding may be of considerable importance for planning Navy training because of the possibility of a loss of motivation and consequent loss of learning efficiency when instruction is exclusively by one method. Further data on this point occurs below.

Student Comments

Authors of most studies reported many spontaneous favorable comments by students. Comments were deliberately collected in the Oscilloscope Guidance study. Trainees were asked to "write down your impressions of the course." Data from 45 students are given in Table 9.

Favorable comments outnumbered unfavorable ones by a ratio of 5 to 1. Over half of the students mentioned that the instruction maintained their interest, kept them alert, etc. A number of students specifically mentioned that they had trouble concentrating or even keeping awake after a steady diet of several weeks of self-instruction study booklets.

Other common favorable comments were positive comments of a general nature and comments on effectiveness and efficiency of instruction. The most frequent type of unfavorable comment concerned initial problems in adapting to the instruction. This was the first exposure of the trainees to CBT.

TABLE 9

STUDENT COMMENTS ON OSCILLOSCOPE COURSE

Type of Comment	Number
Favorable	98
Unfavorable	21
Most Frequent Comments	**Percent of Students**
"Holds interest", "not boring", etc.	58
"Great!", "fantastic", etc.	44
"OK", "good", etc.	18
"More effective than other methods", etc.	36
"Learn at faster rate", etc.	13
"Difficult to get used to", "trouble at first", etc.	16
"Couldn't back up when wanted to", etc.	7

Reliability and Maintenance

Reliability During Experimental Studies

Records were kept of system and communication problems occurring during each study except the Part Task Simulator experiment. Table 10 gives a summary of this data. Transmission line errors were common in most studies. Occasionally, errors were so bad that authoring or executing a course was impossible. For students, the principal problem was distortion of displays. In the more complex lessons, this sometimes made it necessary to sign off and back on to obtain a usable display.

ECS failures occurred in only two studies, due to a temporary lack of sufficient storage available to the NAVPERSRANDCEN site.

System crashes occurred in all studies. Although downtime was usually short, student data was almost always lost, necessitating use of extra students to complete the experimental projects.

Maintenance

In-house maintenance involved trouble analyses and isolation to major subassemblies (e.g., plasma panel), multiplexer, phone lines, or site controller, as well as shipment and replacement of parts. This maintenance was performed by an experienced electronics technician and required about 20% of his time (about one day per week). Hardware covered included 12 PLATO terminals with slide selectors and touch panels, three multiplexers, and one Varian printout unit.

TABLE 10

PERCENT OF STUDENTS EXPERIENCING SYSTEM/TRANSMISSION PROBLEMS

Course	Sine Ratio	Remedial Math	O'scope simulation	Multimeter	Recipe Conversion	O'scope Guidance
No. Stu.	53	63	34	57	48	51
Date	3/74-4/74	4/74-5/74	6/74-10/74	10/74-11/74	1/75-4/75	6/75-7/75
Line errors						
Few	--	--	14	--	10	39
Some	21	73	23	12	43	50
Many	3	8	23	15	29	9
Sign-offs	--	--	11	18	18	52
ECS Failure	--	--	--	14	4	--
Crashes						
1	15	17	23	32	35	--
2	--	--	23	14	21	7
3	--	--	--	2	8	--

The electronics technican felt that the reliability of the terminal was very good. Part of the maintenance problems were due to the fact that it was a new system requiring "debugging." The hardcopy device was less reliable, requiring constant care to work properly.

Maintenance facilities provided by the University of Illinois were excellent. Most of the time, replacement panels, power supplies, and logic cards were available for immediate shipment and required about 4 days for delivery by air freight. An operational course would probably require a local supply of parts so that a faulty terminal could quickly be returned to service.

PLATO Management Capabilities

Student Performance Data

The studies conducted in this project required more extensive data collection than that provided by the CERL data system. Accordingly, a

data collection and analysis package was developed which would track a student's progress through a lesson as well as supply summarizing data. The data management system (DMS) utilizes features of the CERL data storage lesson and proctor control lesson combined with special data routines. Essentially, the way it works is by use of the TUTOR command Output L to transmit the contents of 10 variables from the student record into the data storage lesson. A routine was developed to accumulate data on 30 response units into the 10 variables. This data includes a unique number used for identifying a unit, latency in seconds spent in the unit, and a wrong response identifier.

A display lesson is available to allow the author access to the data storage. Figure 1 shows an example of an actual record. The record lists the student ID number, the response unit, latency, and the actual response (an asterisk indicates an error). This particular example shows performance on the written posttest (Units 1-14) and on a performance (pf) test. Author comments are also inserted in the record to easily identify such things as posttest score and time, sign offs, etc. The type of data illustrated in Figure 1 is particularly useful for evaluating and revising instruction.

The student record display lesson uses 2000 words of ECS. In addition up to 3000 words of common may be used to store student data. Only 1500 words of common were actually used in these studies to store the data from a group of students.

Computer-Managed Instruction

Although the PLATO system was not designed for management of off-line instruction, it appears that it is easily capable of doing so. An analysis was made of the storage and equipment requirements for a self-instructional Navy course such as Basic Electricity and Electronics Individualized Learning System (BEEINLES) which is currently computer-managed. The BEEINLES CMI system stores trainee identification and training history data and provides test feedback, training prescriptions, and scheduling information.

Table 11 shows a suggested student record format which would optimize data storage space. Based on this format, it would take between 12-20 words (60 bits each) to record this data on 30 modules. About 200 student records can be kept in each 1-part lesson space. Thus, an enrollment of 600 students would require three lesson spaces for data storage.

In addition, each 1-part lesson would have an attached 1-part lesson that would contain feedback, training prescriptions, and routines for automatically updating student data. Routines for providing management information would also be included. Management information provided might include student rosters, individual records and summary data on module scores, completion times, etc.

PAGE 5 LESSON jim TIME 14.26.14. DATE 06/17/75

ID NO	UNIT NO	LAT MIN	*	RESPONSE (grped by 15)	ID NO	UNIT NO	LAT MIN	*	RESPONSE (grped by 15)
405	92	9.6			405	4002	0.0		100% postest
405	905	0.1		11	405	3012	0.0		9' postest
405	906	0.3	*	61.875	405	3234	2.0		
405	906	4.0	*	64.102	405	3013	0.0		2' callinst
405	92	0.8			405	3354	1.8		
405	906	0.2		130	405	3014	0.0		2' pftrace
405	3010	0.0		15' pt2pr3	405	3465	3.0		
405	2626	0.1			405	3015	0.0		3' pfprobe
405	93	0.9			405	3646	0.0		
405	3011	0.0		1' trngrev	405	2001	1.7		1
405	2687	0.1			405	2002	0.5		2.4
405	1	0.4		d	405	2003	0.3		24
405	2	0.4		intensity	405	2004	2.1		5
405	3	0.5		sensitivity	405	2005	0.2		2.5
405	4	0.4		sweep time	405	2006	0.2		12.5
405	5	0.4		preset	405	2007	0.8	*	800
405	6	0.6		trigger slope	405	4003	0.0		95% pf v f
405	7	0.3		int	405	3016	0.0		6' pf v f
405	8	0.3		b	405	3992	1.9		
405	9	0.3		a	405	3017	0.0		2' feedbk
405	10	0.3		d	405	33	0.0		
405	11	1.3		c	405	33	0.0		13.22.42.end
405	12	0.5		a					
405	13	1.0		1.25					
405	14	2.4		6.66khz					

TOTAL LATENCY IS 170.3 min for 254 UNITS

Figure 1. Student data trail display.

TABLE 11

CMI DATA FORMAT

Bits	Data Field
20	Social Security Number
36 or 80	Name (6 characters for personalized feedback or 30 characters for full name)
5	Learning center
8	Carrel number
12	Course start date
	Module data (each module):
12	Start date
11	Start time
5	Elapsed time in module
4	Lesson tests (pass-fail) (e.g., 4 tests)
16	Diagnostic tests (not taken - pass-fail)
7	Module test score

There are at least three possible ways of inputting data into the CMI system. One would be by means of an optical scanner. This would probably be necessary for large enrollment courses and would require developing an appropriate interface between the scanner and the PLATO system. A second method would also use off-line testing with the student using the terminal to enter his answers after completing the test. The touch panel would be quite useful for this. A third method would be on-line testing. This would be particularly helpful for the final module tests, as test items could be randomly chosen from an item bank, preventing students from obtaining a copy of the exams. CMI tests are commonly multiple choice, so very little lesson space would be required to store tests and associated response processing.

The hardcopy device could be used for printing out training prescriptions, but one device is probably too slow and unreliable to handle learning centers containing 120 students such as those used in BEGINLES.

Discussion of PLATO Features and Capabilities

Stimulus Presentations

The plasma screen is the outstanding feature of the PLATO terminal. Its capabilities for displays of all kinds, including modifiable graphics, were extensively used in the materials developed in this project. The ease with which displays may be coordinated with touch panel inputs makes the screen very useful for simulations of many kinds of interactive tasks. The speed of writing is too slow for animation involving large or complex graphics, although methods for greatly speeding up display presentations are under development. Displays are highly readable, without any tiring flicker. The principal advantage of the plasma screen from an economic point of view is that displays do not need to be refreshed, making dispersal of terminals feasible.

The microfiche projection system is unsatisfactory in its present form. Its chief advantage over an external projector would seem to be the coordination of the back projected images with plasma screen writing. This was attempted in the oscilloscope studies with poor results. Alignment of images and screen displays was very difficult and varied from copy to copy of the microfiche. In addition, screen writing overlaid on images was extremely difficult to read. Attempts to use rear projected images of job aid cards containing interpolation scales--lines, marks, and numbers--were unsuccessful in the Recipe Conversion study. Graphics and hardcopy handouts had to be used instead. Quality of images was often poor, even with very good original photographs, because of the several stages required in production of microfiche. Time required to produce and revise microfiche was much longer than for comparable screen material. Use of the image projector requires a compressed air supply.

The random-access audio unit was not experimentally evaluated in this project. It also requires an air supply.

Interactive Capabilities

The keyboard was judged good by most users. It was easy to use and had very few maintenance problems. The special function keys ("help," "data," etc.) were liked by some authors but were not used by all. They are not essential and require the coder to have a knowledge of the special branching logic involved in their use.

The touch panel was quite popular. It considerably augmented PLATO's simulation capabilities, as described previously, and was often used in place of or as an alternative to alphanumerics and function keys for multiple choice responding and branching. The best example of its use was in the Part Task Trainer study where sets of push button switches of the S-3A copilot INCOS panel were graphically simulated. Use of the touch panel to interact with the display closely approximated the perceptual-motor response required with actual gear.

Course Management

PLATO facilities for this are very good. The router lesson and other features provide control and monitoring of student progress. Standard student performance data are readily kept, and the system has ample capabilities for collection and analysis of more extensive data required for formative evaluation and revision of new courses. The system is also easily capable of management of off-line instruction, although special input/output equipment would be required for large-scale applications.

Course Preparation

TUTOR is a very powerful language and was found to be quite useful for the varied and often complex applications studied in this project. Coding of simpler types of instruction is straightforward. TUTOR's chief drawback is that it contains too many unnecessary complexities (variable formatting, etc.) and requires extensive experience for a coder to become expert. For this reason the most cost effective approach to course preparation is to separate the authoring and coding functions, with separate personnel assigned to each task.

Although comparisons with other systems are difficult because each system has special advantages, the PLATO editing system was judged to be excellent in comparison to most current (line-editing) systems. PLATO has many special features, such as functions to build up graphic displays, material location functions, and error detection capabilities.

Driver lessons, using a preplanned strategy for development and presentation of instruction, were shown to be readily implementable on PLATO. Such driver lessons are an important way of reducing course development costs.

The hardcopy device is just about essential for developing and administering a course. It was heavily used in this project for materials development and debugging, documentation of course content, and for student records and performance data.

System Capacity

The PLATO system is designed to handle a very large number of students. The current system at the University of Illinois has two million words of extended core storage and about 950 terminals. System "overhead" requires 400,000 words of ECS, so there is an average of about 1700 words of ECS available per terminal. Since the average hour of on-line instruction requires about 4000 to 10,000 words, it is clear that efficient use of terminals requires that several students be on a lesson simultaneously. A problem with a large system is that there may be little courseware available initially, so that it cannot be expected to be cost effective unless used over a period of several years.

The use of highly adaptive, self-paced CBI imposes severe limitations on the number of terminals that the system can handle. It was previously shown (Table 4) that the simulation lessons required about twice as much ECS as nonsimulation lessons. An extreme example of the limitation on terminal usage can be illustrated for the Navy's Site 24 on the PLATO IV System consisting of 16 terminals; a total base ECS of 24,600 words (approximately 1530 words per terminal in student mode) is allocated. The INCOS lessons for part-task training on the S-3A copilot panel require that six lesson files be available to each student in a student-controlled, self-paced learning condition. Each lesson was originally developed with an average size of 8000 words. Professional programmer/coders on the INCOS project have recently judged that the lessons cannot be reduced below 6000 words to function; two new lesson files would have to be added. This would still mean that when only four students are each receiving training on different INCOS lessons, the other 12 (75%) terminals in the site are rendered functionless for use by other students.

The driver lesson, "learner," designed by NAVPERSRANDCEN researchers to facilitate lesson development of CBI, offers another example of this problem. The driver requires approximately 1500 words of ECS. This is the base ECS allocation before adding instructional content. At best the minimum size lesson would be at least 3000 or 4000 words in length. This means that use of the driver reduces terminal utilization by 50% when students are scattered on different lessons.

Reliability

The amount of system downtime during prime time was very small, despite the fact that the system was undergoing experimental development. System crashes while running students were usually short, the worst problem being the loss of student data.

Terminal reliability was satisfactory. Much of the downtime was due to design/production faults which have since been corrected.

Transmission line errors, due to the long distance between the University of Illinois and San Diego, were a continual source of annoyance for authors and students, although they normally did not seriously interfere with use of the terminals. Occasionally, however, transmission was so bad that some of the terminals were unusable.

DEVELOPMENT OF COMPUTER-BASED MATERIALS

General Description

A summary of subject matter areas, amount (hours) of instructional lesson materials, instructional strategies, and course sequencing in the computer-based materials developed for the PLATO research studies is presented in Table 12.

Subject matter areas ranged from mathematics and recipe conversion to simulation of electronic test equipment and the S-3A copilot INCOS panel. Seven unique application areas were represented.

The number of instructional lesson hours of computer-based materials developed for each study varied widely and was influenced by the research design, training topic, purpose of the study, and manpower constraints. The reported figures do not necessarily reflect the actual number of student contact hours of instruction (average time spent by a single student to go through the materials), because sometimes more than one form or version of the materials was developed for a study. The Recipe Conversion study, for instance, developed two different lessons for teaching; each approach averaged 4.4 student contact hours of instruction for a total of 8.8 hours of instructional materials developed and used in the study.

Three basic types of instructional strategies were employed. Tutorial strategies were used in six studies, simulation in four studies, and drill and practice in one study. The Learner Control study was unique because it consisted of computer logics for course sequencing using student control and was designed to accommodate to any instructional strategy.

Course sequencing employed in each of the PLATO studies was reported in terms of the percentage of student control allowed over selection of content and quantity of the lesson materials. No study gave students less than 20% control over the course sequencing; half of the studies gave students maximum (90% or greater) control.

Development Method

All but two studies used a team approach for developing their computer-based materials. A team usually consisted of an author and a coder. The author was responsible for planning the study and writing content of the course, and the coder was responsible for transcribing (programming/coding) content onto the system in the TUTOR language. The typical author was a research psychologist who had previous experience developing computer-based training materials but who was naive toward the subject matter area of the present research study. The typical coder was either a San Diego State University contract student or a member of the computer personnel staff on the project effort; all coders were new to TUTOR at the beginning of the effort.

TABLE 12

SUMMARY DESCRIPTION OF COMPUTER-BASED MATERIALS

Study	1	2	3	4	5	6	7	8
Description	Remedial Math	O'scope Simulation	Sine-Ratio	Multimeter Simulation	Learner Control	Recipe Conversion	O'scope Guidance	Part Task Trainer
Subject Matter Area/Topic	Algebra Powers of ten	Electronics Oscilloscope	Sine-Ratio Trigonometry	Electronics Multimeter	CBT Lesson Development	Math & Recipe Conversion	Electronics Oscilloscope	S-3A Copilot INCOS Panel
Instructional Hours	3.0	5.2	1.2	4.0	2.0	8.8	12.0	3.0
Instructional Strategy	Drill & Practice Games	Simulation Tutorial	Tutorial	Simulation Tutorial	(Strategy Optional)	Tutorial	Simulation Tutorial	Simulation Tutorial Practice
Course Sequencing (% Student Control)	30	20	30	93	100	100	55	100

The average percent of development effort expended in authoring and in programming/coding activities for all studies was found to be 38% in authoring (range 11% to 64%) and 62% in coding (range 36% to 89%) (see Table 13). The percentages were obtained by dividing the estimated time (hours) spent in each activity by the total development time.

TABLE 13

PERCENTAGE OF DEVELOPMENT EFFORT BY TEAM MEMBER

Team Member	Study								
	1	2	3	4	5	6	7	8	All
Author (%)	43	44	64	19	35	35	51	11	38
Coder (%)	57	56	36	81	65	65	49	89	62

The method by which the programming/coding was accomplished in each study indicates the extent of the team effort. Table 14 presents an estimated percentage of time spent by author and/or coder in programming/coding materials. A team approach was used in all but two studies where the authors preferred coding their own materials. For the 6 studies, coders did 95% or more of the programming/coding activity in 4 studies and 70% or more in two studies.

TABLE 14

PROGRAMMING/CODING METHOD

Programming/ Coding Person	Study							
	1	2	3	4	5	6	7	8
Author (%)	5	30	5	100	100	5	20	0
Coder (%)	95	70	95	0	0	95	80	100

Learner Control Driver

The purpose of Research Study Five, Learner Control, was to develop a preprogrammed, "universal" driver which could be used as an aid by authors and coders to reduce the effort of preparing CBI lesson materials. The Learner Control Driver was used in the preparation of lesson materials for both Study Four, Multimeter Simulation, and Study Six, Recipe Conversion. The estimated course development time of 77 man hours per instructional hour of materials in Study Six appears to strongly support the Learner Control Driver as a feasible method to reduce costs. It was not possible to separate out possible savings from use of the driver in Study Four because the development time included that used in the programming of several experimental models and reiterations of the multimeter simulation.

Man-Hours of Effort Expended

Table 15 lists the number of instructional hours of computer-based materials developed, the total man-hours of effort estimated in authoring and coding activities, and the average man-hours of effort required to develop each lesson hour of computer based materials. The difference in effort required to produce materials for the Multimeter Simulation study (560 man hours/lesson hour) and for the Recipe Conversion study (77 man hours/lesson hour) is in the magnitude of seven to one.

A grand total of 39.2 lesson hours of computer-based materials were developed at the cost of 12,332 man-hours of effort, a mean cost of 314.6 man-hours per lesson hour.

TABLE 15

MAN-HOURS EXPENDED IN DEVELOPMENT

Item	Research Study 1 Remedial Math	2 O'scope Simul.	3 Sine-Ratio	4 Multimeter Simul.	5 Learner Control	6 Recipe Convers.	7 O'scope Guidance	8 Part-Task Trainer	Combined
No. Instructional Hours Developed	3.0	5.2	1.2	4.0	2.0	8.8	12.0	3.0	39.2
Authoring (Hours)	500	600	208	428	496	240	1900	161	4533
Coding (Hours)	650	770	116	1810	933	440	1800	1280	7799
Total (Hours)	1150	1370	324	2238	1429	680	3700	1441	12,332
Mean Man-Hours Per Lesson Hour	350	262	270	560	714	77	308	480	315

PLATO COST ANALYSIS

Two cost questions are of major importance in the evaluation of any instructional delivery system: (1) How much does it cost to develop instructional materials for the system? and (2) How much does it cost to present the materials on the system to students?

Instructional Materials Development Cost

The studies conducted in this project provided information on the relative importance of factors determining course development costs. The project was not designed to provide direct estimates of costs to the Navy of developing operational materials for a "PLATO-like system." To evaluate the cost of developing instructional materials for operational training applications in the Navy, certain requirements must be met:

1. Materials must be designed for real training, i.e., either as a supplement or as a replacement for an actual existing or proposed curriculum.

2. Materials must be developed under the same type of conditions and with the same personnel that would be expected to be used in an operational situation.

3. Sufficient quantities or amounts of materials should be developed across a wide variety of training application areas to provide for generalizations of findings.

4. Accurate records must be available for the various types of man-hours of efforts required to develop and prepare the instructional materials.

Materials developed for the project were experimental and designed only for the purpose of testing specific research questions. Instructional materials which were developed were not designed as a prototype or test-bed for operational evaluation. Research personnel developed the materials. Although the range of subject matter areas, Navy training applications, was broad (see Table 12), the quantities of CBI materials developed in many studies were not sufficient to provide sensitive or reliable measures of training effectiveness or to be representative of operational training situations. Researchers were involved in a variety of activities while developing their instructional materials. These activities included experimental design and control management, testing different presentation formats, investigating instructional strategies and logics, as well as preparing extensive automated recording procedures. Only very rough estimates could be made of actual man-hours expended on the development of instructional materials.

Readers are referred to a recent report, "Volume I, Evaluation of the PLATO IV System in a Military Training Environment, Final Report," published by the U. S. Army Ordnance Center and School, Aberdeen Proving

Grounds, Maryland. This report describes the Army's effort in the ARPA joint-supported, tri-service project. The Army's goal was to evaluate PLATO for military training in a test bed situation; a specific subgoal was to estimate the cost of developing operational training materials for the PLATO IV system. The report states that an average time of 283.6 man-hours was spent on each of the 30 instructional hours of CAI developed.

In the Navy effort, the average man-hours expended per CBI lesson hour was 314.6 (see Table 14) for the 39 student contact hours of instruction developed, which was very close to the figure reported by the Army. Caution is expressed, though, against making too strong a generalization from these data. The data in Table 14 clearly show that experimentally developed CBI materials, similar and dissimilar subject matter topics, specific application areas, and various instructional strategies can require markedly different expenditures of effort. Other factors which influenced development man-hours included: (1) the experience and expertise of personnel employed, (2) the degree of individualization and student interaction involved, (3) the level and complexity of the subject matter content, and (4) the kinds of presentation and types of response modes required.

An example which illustrates the wide differences in effort expended across different studies, subject matter areas, instructional strategies, and performance requirements developed by research personnel in the NAVPERSRANDCEN PLATO Evaluation Project is the Recipe Conversion Study. Here CBI materials were developed with an effort of only 77 man-hours per student contact hour. With only 4 hours of CBI, experimental students scored as well as classroom controls who had received 4 days (28 hours) of recipe conversion instruction. Another example is the Part-Task Training Study where 3 student contact hours of instruction averaged 480 man-hours of effort per hour to develop. Copilots using PLATO only 3 hours performed faster and more effectively than controls who studied a workbook 8 hours and spent 1 hour practicing in a $250/hour Position Trainer. Both studies demonstrate possibilities for cost-effective CBI training in: (1) recipe conversion with Mess Management Specialist enlisted personnel because of the relatively small man effort required to develop the CBI and the large savings accured in training time (4 hours versus 23 hours); and (2) part-task training on the S-3A Copilot INCOS panel because CBI, though developed at a high cost, was less expensive than conventional copilot training, saved valuable training time (3 hours versus 8 hours), and offered a means of freeing an expensive high-fidelity simulator for more complex and advanced training use.

The above examples help to point out important problems that are encountered trying to select an instructional development cost index which is valid for comparing instructional methods. A few of the common indexes are:

1. Instructional Development Cost =

   Number of Man-Hours Expended x Cost per Man-Hour

2. Instructional Development Cost per Hour of Material =

Instructional Development Cost ÷
Number of Hours of Material Developed

3. Instructional Development Cost per Student Contact Hour =

Instructional Development Cost per Hour ÷ Number Student Contact Hours during Life of Materials

4. Instructional Development Cost per Student =

Instructional Development Cost per Student Contact Hour x Number of Hours of Instruction

Only index (4) above would show a cost savings due to a decrease in training time resulting from the instructional method. None of the indexes are capable of reflecting the potential cost benefit that might be attributable to increased or enhanced performance. Finally, the instructional cost must include the cost for delivery or presentation of the materials to the student; this cost is examined and discussed in the next section.

In summary, four points may be made about course development costs:

1. A large part of the costs, e.g., authoring and revision costs, would be incurred whether the instruction was CBI or some other form of individualized instruction. In CBI, the use of driver lessons would reduce both authoring and coding costs.

2. PLATO compares well with current systems with regard to coding costs. The editing facility is very good and the language is useful for graphics and interactive applications.

3. PLATO is well suited for course revisions because of the large performance analysis capability.

4. Development costs depend heavily on the type of application. Using the man-hour data from this project (see Table 15), average personnel costs of $8.00 per hour, 10-year amortization, and a yearly student enrollment of 1000 trainees, the development cost per student contact hour could range from about 6 to 45 cents.

Instructional Delivery (Presentation) Cost Estimates

During the life of the project, all delivery costs were borne by ARPA. These costs were comprised of two main components: (1) terminals and related hardware costs, and (2) time-sharing, communications and maintenance costs. Terminals represent a one-time cost; the other component represents a fixed or constant annual cost.

Terminals

At remote sites, such as San Diego, a special device called a multiplexer is necessary to interface terminals with phone lines (communications) connected to the central processing computer of the PLATO IV System at the University of Illinois. The number of terminals which can be interfaced to a single phone line is partially controlled by the design of the multiplexer. Current production models are designed to interface with from one to four terminals. Because a multiplexer costs almost the same as a terminal, the most cost-effective minimum configuration of hardware at a remote site consists of one multiplexer and four terminals. All further discussion in this section will assume the use of this minimum configuration in cost estimates.

An accepted method of expressing one-time cost for hardware which has a useful life of more than 1 year is to figure cost per year based on its estimated life: Cost per Year = one-time cost/years of life. This method is also referred to as amortization of cost.

Hardware costs are also frequently expressed as cost per hour or cost per student contact hour. This method of determining and reporting cost is one of the most important in the analysis of true cost effectiveness of an instructional delivery system. It is a cost estimate which must always be carefully determined and analyzed when making implementation decisions. The actual number of hours that students are expected to use the terminals each year for training is the base of the analysis for cost per student contact hour. In other words, whenever an hourly cost estimate is given, it implies that the system can deliver instruction at a certain cost per hour. The estimate is not meaningful, however, unless information is also provided which tells how many hours per year students must use the system in order to achieve that cost. A common base used for multimedia systems, such as computer-based instructional systems, that have the capability and capacity for large-scale utilization is 2000 student contact hours per year per terminal. This base assumes that each terminal is used 8 hours per day, 5 days per week, 50 weeks per year (8 x 5 x 50 = 2000 student contact hours per year per terminal).

Current estimates of the cost of the PLATO IV plasma screen terminal and keyboard with options such as touch panel and microfiche slide selector range between $8000 and $13,000, with an average of approximately $10,500. Using this average cost of $10,500 per terminal, Table 16 presents a variety of ways of examining the cost of a minimum configuration of hardware and assumes that the multiplexer also costs $10,500. The one-time (and first year) cost of the one multiplexer-four terminal configuration is $52,500 ($10,500 x 4 terminals + a $10,500 multiplexer); amortized over a 10-year life, the configuration would have an annual average cost of $5250. The "hourly" (student contact hour) cost of the configuration, assuming a base usage of 2000 hours per year per terminal is $2.62 per hour. Table 16 also includes the prorated cost per terminal in the minimum configuration; e.g., $.65 per hour if amortized over 10 years.

TABLE 16

TERMINAL PURCHASE COSTS

Amortization	Minimum Configuration (4 Terminals + 1 Multiplexer)		Prorated Per Terminal	
	Annual ($)	Hourly ($)	Annual ($)	Hourly ($)
One-time (1 yr)	52,500	26.56	13,125	6.56
3 year life	17,500	8.75	4,375	2.18
7 year life	7,500	3.75	1,875	.93
10 year life	5,250	2.62	1,312	.65

As long as the cost of the PLATO IV terminal remains at approximately $10,500, the hardware cost figures reflected in Table 16 will remain at that level. A change in the minimum configuration, for instance, a new multiplexer designed to interface 8 or 16 terminals to one phone line, would not change the hardware cost appreciably. However, such a change might significantly reduce expensive communication costs (see discussion below). If mass production were to reduce the price of terminals to $8000 each, the 10-year average cost per hour would be about .50, a 15 cent per hour decrease per terminal.

Time Sharing, Communications, and Maintenance

Unlike the terminal component, this cost area is constant or fixed; it remains the same each year, regardless of how long the system is used. It is determined by the number of terminals that are operated and the distance between the site of the terminals and the University of Illinois PLATO System.

The Time Sharing element is the cost of leasing or renting computer (Cyber-70) time from the University of Illinois PLATO System. The ARPA contract price was $2500 per terminal per year or $10,000 per configuration of four terminals.

The Communication element is the cost of leasing phone line service to connect the terminals with the computer. One phone line, voice grade, twisted pair, was required for each configuration. The multiplexer used during the subproject was capable of separating input and output signals from a single phore line for a maximum of four terminals. Quoted phone rates (24 hours per day) have placed the cost at $1.00 per mile per month.

Government (GSA) rates are approximately one-half that figure at approximately .50 per mile per month. Each phone line between the University of Illinois and San Diego, a distance of about 1800 miles, cost $900 per month or $10,800 per year ($900 x 12 months).

The Maintenance costs are a special fee or charge made on a per terminal basis; they are influenced by the distance of the terminals from the University of Illinois System. These costs are intended to cover terminal maintenance, repair parts, consulting, microfiche production, hardcopy printing, and other miscellaneous services of a similar nature. The charge per San Diego based terminal is estimated at about $1300 or a total of $5200 per configuration of four terminals.

A summary of annual costs for time-sharing, communications, and maintenance for the four terminal configurations at San Diego is given in Table 17. The total annual cost is $26,000. The prorated hourly cost per terminal in a configuration is therefore $3.25 ($26,000 ÷ 8000 hours (4 terminals)).

TABLE 17

ANNUAL TIME SHARING COSTS
MINIMUM TERMINAL CONFIGURATION

Area of Expense	Annual Cost
1. Communication: Phone line @$900/month ($900 x 12 months)	$10,800
2. Time-Sharing: @ $2,500/terminal ($2,500 x 4 terminals)	10,000
3. Maintenance:	5,200
YEARLY TOTAL	$26,000
Prorated hourly cost per terminal ($26,000 ÷ 8,000 hours)	$3.25

Total Delivery Costs

The total cost of CBI via the University of Illinois PLATO IV System on a per student contact hour basis is the sum of the costs for terminals, timesharing, communications, and maintenance. Assuming that (1) the terminals are purchased in minimum configurations and used over a 10-year period, (2) fixed costs (time-sharing, communications, and

maintenance) remain the same each year, and (3) each terminal is used 2000 hours per year, the cost would be $3.90 per student contact hour, as shown in the first column of Table 18.

TABLE 18

COMPARATIVE DELIVERY COSTS PER STUDENT CONTACT HOUR
(10-Year Amortization)

Cost Item	Time Share 4 Terminals		Purchase 250 Terminals	
	PLATO Project	"Local" Use	Full Use (250 x 2000 hrs.)	Buildup (Ave. 125 Terminals)
System (Est. $2,250,000)	-	-	.45	.90
System Management and Maintenance (Est. $170,000/year)	-	-	.34	.68
Time Share ($2500/year)	1.25	1.25	-	-
Terminal ($10,500)	.52	.52	.52	1.04
Terminal Maintenance and Services	.65	.40	.40	.40
Multiplexor ($10,500)	.13	-	-	-
Telephone Lines (.50/mile or $10 month (local))	1.35	.06	.06	.06
TOTAL	$3.90	$2.23	$1.77	$3.08

The $3.90 figure is the cost for terminals located 1800 miles from the computer system. A large part of this cost is due to the long distance. Column 2 of Table 18 shows estimated costs when terminals are installed close to the computer. The estimated savings is $1.67 per student hour. In addition to communication cost reductions, there would also be a maintenance cost reduction because of reduced travel, parts shipments, and delays. (The figure of 40 cents may be too high. After an initial break-in period, the newer versions of the terminal are probably maintainable for $600 each per year, or 30 cents per student contact hour.)

An alternative implementation plan would be to purchase a full PLATO system. Column three of Table 18 shows estimated costs of such a system if 250 terminals could be operated at "full" capacity (2000 hours each per year). The total cost would be $1.77 per student hour. However,

this figure is unrealistic because initially there would be little courseware available. The last column of Table 18 shows costs if the buildup of courseware were rather slow so that, over 10 years, only an average of 125 terminals could be utilized. In this case, costs would total $3.08. Clearly, courseware should be developed as rapidly as possible in order to provide a cost-effective implementation. Also, a larger final implementation, e.g., 500 terminals, would further reduce costs.

Cost Comparisons with other CBI Systems

The subproject mission did not include provisions for evaluating or comparing the cost of the University of Illinois PLATO IV System with the cost of purchasing or time-sharing with other CBI systems in the state-of-the-art.

A special report (Kribs, 1976) prepared by NAVPERSRANDCEN for the Special Projects Office, SP-15, has documented the cost of a variety of CBI systems. The report makes an important point about comparing the hardware (delivery) cost of different CBI systems--stand-alone terminal systems, minicomputer systems, and large PLATO type systems: Cost interacts with number of terminals and communication requirements.

If only a few (e.g., 16 or less) terminals are needed or required, the stand-alone, "intelligent" terminals with their own microcomputers may deliver instruction at the lowest cost per student contact hour. There are no communication costs with this type system.

As the number of required terminals increases (e.g., 32 to 64), the minicomputer type systems become more cost effective than stand-alone systems. Again, there are no communication costs with this type system.

Carrying this comparison one step further, when 500 to 2000 terminals are needed, the large terminal capacity systems like PLATO may prove most cost effective. Communication costs, though, can add significantly to total cost of delivering instruction, because remote location of some terminals may be necessary to utilize all the terminals effectively.

In summary, cost decisions involving implementation of CBI for military training require careful consideration of both the size of system (number of terminals) needed and the requirements for communication hookups.

Finally, it must be emphasized that nothing has been said here about comparing CBI systems for their instructional capabilities, i.e., what one gets for money spent, and what one can or cannot do with a specific system.

CONCLUSIONS

Experimental Findings

1. Remedial Math Study: PLATO is ideally suited for contingency management of learning and practice during training using the wide variety of games available on the system as reinforcers. The use of games as part of feedback confirmation to math practice problems positively influenced student attitudes toward training.

2. Oscilloscope Simulation Study: PLATO successfully taught cognitive skills of voltage and frequency measurement during training on oscilloscope operation using simulation. Training on perceptual-motor skills, e.g., ones requiring skilled manual manipulation, were the least effectively taught. Training using computer-based simulation can greatly reduce the amount of hands-on training needed.

3. Sine-Ratio Study: Graphics were not found to enhance learning of verbally-loaded concepts.

4. Multimeter Simulation Study: PLATO graphics and TUTOR language were highly successful for programming dynamic and interactive simulations of the multimeter. Simulation may offer an instructional technique for reducing cost of training and training equipment.

5. Learner Control Study: The use of a preprogrammed, "universal" driver to control lesson strategy can eliminate a major part of the task of CBI lesson preparation and offers a significant method of saving both author training and lesson preparation time.

6. Recipe Conversion Study: Student-controlled individualized CBI in nontechnical Navy training can be used to markedly decrease training time without degrading the performance of trainees with below average academic skills. Low aptitude students do not appear to have difficulty in using the PLATO terminal.

7. Oscilloscope Guidance Study: Computer guidance of hands-on training is an effective instructional procedure and can reduce or eliminate instructor based tutoring. Part-task procedural training seems to be superior to whole-task training, if the part task is an actual component of the criterion task.

8. Part Task Trainer Study: Part-task training of complex procedural skills via computer-based simulation, i.e., interactive graphics and touch panel response mode of PLATO IV, is technically, operationally, and economically feasible. It can be used to (a) reduce instructor time, (b) reduce student training time, (c) increase performance, and (d) substitute for expensive one-of-a-kind simulators in application areas where initial training is expensive, e.g., flight training.

Instructional Effectiveness

Previous research has already decisively demonstrated the instructional effectiveness of CBI over conventional training methods, especially classroom instruction. It has shown that CBI can produce significant increases in performance and decreases in training time, when the instructional materials have been carefully planned, developed, trial tested, and revised. The reason for the success of CBI is because this automated instructional method is capable of incorporating the necessary laws and principles of learning into the instructional environment for the student.

The PLATO IV System is a CBI system for storing, controlling, and presenting training materials. It appears to be one of the most advanced and flexible systems in the state-of-the-art. Experience during this project leads to the conclusion that the instructional effectiveness of PLATO IV is restricted only by the imagination and skill of the instructional designers using the system. This conclusion is not intended to imply that other CBI systems are not or cannot be instructionally effective for certain types of training. It merely points out the great flexibility and capability of PLATO IV for effectively delivering training and instruction.

A final conclusion on the instructional effectiveness of PLATO IV as a delivery system for CBI is difficult because, during the evaluation of the system, decisions regarding its operations have been under the control of the University of Illinois. The system, as currently configured with 950 terminals and a base ECS allocation of 1500 words per terminal in student mode, may not be operationally useful for self-paced training. There is considerable question as to whether lessons which are individualized, adaptive, self-paced, and which may or may not use interactive graphic routines for simulation can be developed with 1500 words or less. If they cannot, then the ECS allocation must be increased and corresponding adjustments must be made in the system configuration, i.e., the number of terminals must be decreased. A configuration of 500 terminals may be more operationally feasible.

Training Applications

PLATO IV is capable of providing instruction across a wide spectrum of Navy training. Over seven unique application areas are represented in this effort; subject matter ranged from mathematics, recipe conversion, simulation of electronic test equipment and the S-3A copilot INCOS panel, to social training. Students used in the studies included recruits with below and above average aptitudes, recruit company commanders, and officers.

PLATO IV is highly effective for training conceptual and cognitive skills. Because of its interactive capability, students can practice on-the-job skills involving sequential and procedural learning tasks. Perceptual-motor responses are less effectively taught using simulation

because of the lack of response fidelity, e.g., learning to manipulate an oscilloscope probe by looking at graphics and reading text is not as effective as learning a complex switch pressing sequence by touching graphic displays of the switches.

One of the most innovative PLATO IV training applications is the use of its programmable interactive graphic displays for simulation. Several examples are: (1) simulation of operational equipment, gear, and hardware for training operator and maintenance skills; (2) simulation of weapon systems and tactical situations for individual or team training; and (3) simulation of interpersonal situations for training social interactions and behavior. In each case, PLATO can integrate a training function and provide interactive responding, feedback, guidance, management, and performance measurement and evaluation.

PLATO Features

The most useful features of the terminal were found to be the plasma screen, the touch panel, and the keyboard. These three features provided an ample capability for stimulus displays, student responding, and course sequencing. The image projector was of very limited usefulness because of problems in alignment, readability, and preparation of microfiches. The audio capability may only be needed for highly specialized training requirements.

The system is especially well suited for training tasks involving extensive student interactions, such as test equipment operation and part-task simulation training. Valuable features include the graphics capability, the touch panel, and the broad usefulness of the TUTOR language.

User acceptance was very good. Authors particularly mentioned the plasma screen, the touch panel, TUTOR, and user services and aids. Students gave high ratings to all features of instruction except the quality of the photographs shown on the image projector.

Editing and coding capabilities were judged to be very good. TUTOR is a very powerful CAI language with extensive uses for displays, response processing, and course control. Since complex applications require an experienced coder, it is recommended that authoring and coding functions be done by separate personnel. The hardcopy device is practically essential for efficient editing, course documentation, and student data analysis.

PLATO is a very large system. This means it has excellent capabilities for data management, course management, and collection of data for course evaluation and modification. It also means that a lot of course material is required if the system is to be used efficiently, i.e., enough to keep 250 to 1000 terminals busy. Finally, if most applications utilize highly interactive, adaptive training, there will be a restriction on the number of terminals imposed by the high ECS requirements. A system configured for 2,000,000 words of ECS could probably support a maximum of 500 terminals.

The system was quite reliable during the project, with very few "crashes." Terminals were also judged to have satisfactory reliability, particularly later versions. Line errors, due to long-distance transmission, were a continual annoyance and were most troublesome when displaying graphics. Reliability of the hardcopy device was very poor.

CBI Material Development Method and Effort

The use of a team may be the most efficient and effective method for developing CBI lesson materials. A minimum team divides the authoring and programming/coding activities; this allows each team member to specialize. Extensive experience is required for a coder to become an expert in the use of TUTOR. An author must (1) be familiar with the subject matter, and (2) be able to determine training objectives, design instructional strategies, and apply principles of learning; and know the capabilities of the CBI system being employed.

Driver lessons, using preprogrammed logics for development and presentation of instruction, are readily implementable on PLATO IV. Drivers offer a method for reducing lesson development effort.

The most important factors influencing man-hours of effort in the development of lesson courseware are: (1) the experience and expertise of personnel employed, (2) the degree of individualization and student interaction involved, (3) the level and complexity of the subject matter content, and (4) the kinds of text and graphic presentation and types of response modes required.

Man-hours of effort required to develop a student hour of instruction varied by a factor of seven between the experimentally developed lessons of the eight research studies in this project. With a range of from 80 to over 550, a mean of 315 man-hours were expended per lesson hour. This figure closely approximated the 284 man-hours reported by the Army during their PLATO project. A conservative estimate of the time required to develop one student hour of instruction on the PLATO IV System is, therefore, probably somewhere between 200 and 400 man-hours.

CBI Delivery Cost

Delivery (presentation) costs are comprised of two main components, hardware costs and time-sharing, communications and maintenance costs. Factors influencing the costs include: (a) instructional capability, (b) whether the system is purchased or time-shared, (c) whether terminals are purchased or leased, (d) the distance of terminals from the main CPU (communication requirements), and (e) the number of terminals (utilization).

A PLATO terminal purchased at $10,500 would have a 10-year amortized cost of about 65 cents per hour based on a utilization of 2000 hours per

year. The annual, prorated cost of time-sharing with the University of Illinois PLATO System is approximately $3.90 per terminal hour based on a minimum configuration of four terminals located in San Diego. Forty percent of the fixed cost for San Diego is for communications. If a system were available locally, the cost would be $2.25 per hour.

The purchase of a PLATO IV System configured for 250 terminals would incur a one-time cost of about two and one-quarter million dollars. Amortized over 10 years, with all terminals used locally, and utilization of 2000 hours per terminal per year, the cost would be from $1.75 to $3.00 per terminal hour, depending on the speed of development of course materials.

CBI Development Cost

The PLATO IV System compares well with other CBI systems and multimedia methods with regard to the cost of development of instructional materials.

Development costs decrease as the number of hours of instruction increases: (1) It usually takes longer to develop the first or early hours of a course, and (2) Cost effectiveness, resulting from training time savings over conventional instruction, may not occur until several hours of adaptive, self-paced CBI are used in a course.

If a large number of courses and hours of instruction were going to be implemented on a PLATO IV type delivery system, cost could be minimized by organizing and maintaining an experienced and specialized team of authors, programmer/coders, and instructional technologists to develop and/or assist in the development of instructional materials.

Assuming that an average of 200 to 400 man-hours of effort is required for the development of each hour of instruction and that each man-hour cost $8.00, the development cost would be between $1600 and $3200. If the course were to be used by 500 students each year for 10 years, the development cost per student contact hour would range from 32 to 64 cents.

RECOMMENDATIONS

There are two possibilities for implementation of training using a PLATO system. One is to purchase a system; the other is to lease time from the University of Illinois or from another PLATO installation.

1. The purchase of a PLATO system cannot be recommended at this time. It is not known if there is sufficient need for the type of training provided by an interactive CBT system to justify the use of a large PLATO-type system. Such a system must be operated at full capacity in order to provide maximum cost benefits. Also the relative cost effectiveness of CBT and other methods of instruction will vary widely from application to application, and data on these costs are not readily available. Finally, many of the capabilities needed for effective CBT development, delivery, and evaluation are available on other CBT systems. The capabilities and costs of PLATO should be compared to those of competitive CBT systems before making a purchase decision.

2. Leasing of time on a PLATO system has drawbacks. The University of Illinois system has so many terminals that it is difficult to provide enough ECS to allow adequate individualization of instruction. This is particularly true for complex part-task simulations with high ECS requirements. Leasing of time from a private vendor may cost more. One reason for this is that the University of Illinois project has been partly subsidized by research funds. In any case, potential users should keep in mind that maximum cost benefits can only be realized if terminals are fully utilized and are located close enough to the computer system to avoid excessive communication costs. Where only a few terminals are needed, small systems and/or stand alone terminals may be more cost effective.

3. In order to assess the proper role of CBT systems in Navy training, two approaches are suggested. First, an analysis should be made of the potential for Navy CBT applications and their cost effectiveness in comparison to other training options. It was outside the scope of this project to do the necessary needs analysis that would make it possible to identify specific Navy training needs and their current and/or anticipated costs. This information is required before it is possible to make recommendations on the operational utility and potential cost and training benefits that may be achieved using a large CBT system. If there is a high requirement or demand for CBT, then a large system may be more cost effective than the use of many smaller systems (Kribs, 1976). A large CBT system would be most useful in an area such as San Diego where a large variety of users could access the system and communication costs could be minimized. A needs analysis should be made within the next few years. Otherwise there is a risk of the proliferation of many small systems by individual training groups, without an overall Navy plan for introducing CBT on the most cost effective basis.

4. Second, because of the unusually successful applications of interactive computer graphics to simulate operational equipment and to provide part-task training, it is recommended that this methodology be considered as a cost effective training supplement or substitute for

expensive high fidelity simulators or trainers. Additional R&D is essential to determine the kinds of skills that can be best trained using this methodology and to isolate the necessary instructional elements which must be present to yield effective training using CBT simulations.

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